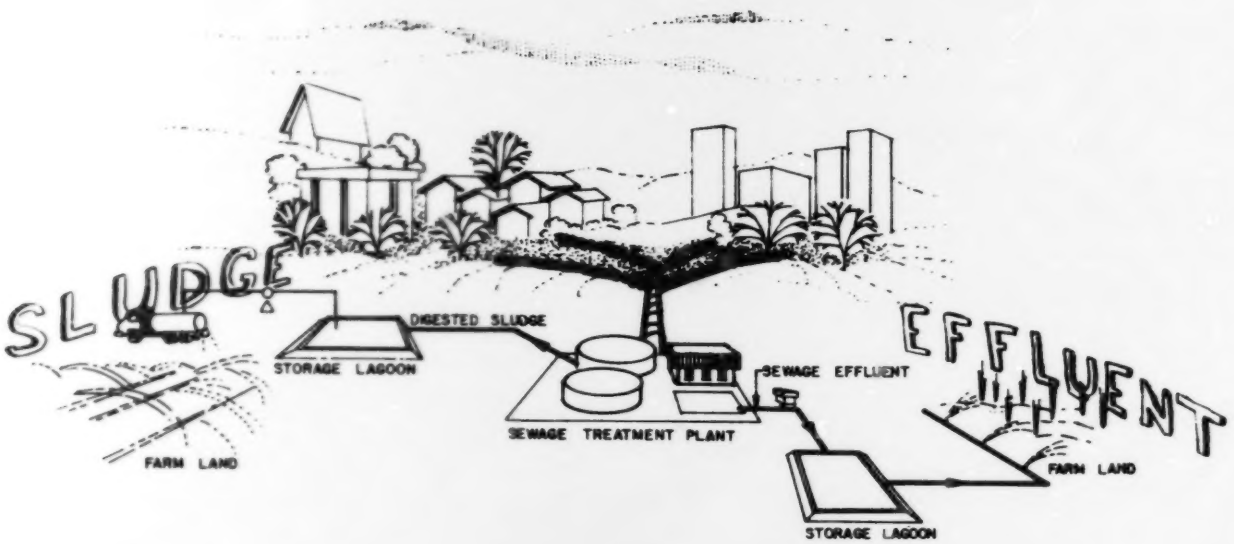
# sewage as a resource

## LAND APPLICATION OF SEWAGE EFFLUENTS AND SLUDGE




Alberta
ENVIRONMENT

# PREFACE

This document is intended to acquaint people with the concept of reusing sewage effluents and sludges through their application to land. It outlines the basic methods of sewage treatment and reviews the general characteristics of sewage effluents and sludges. Land application methods for reusing sewage effluents and sludges are presented and specific examples of successful recycling operations are discussed.

It is hoped this document will help expand the public's knowledge and awareness of land application as a method of reusing sewage effluents and sludges.

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# THE PAST, THE PRESENT, AND THE FUTURE...

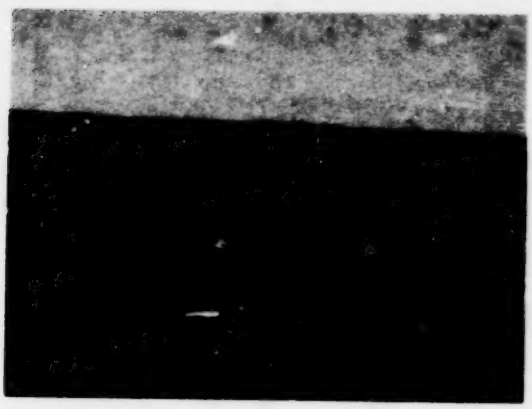
The practice of applying sewage effluents and sludges to land is not new and probably dates back to the time of the early Greek civilization. In Europe, in the second half of the 19th century, land application of raw sewage was commonly used as a way of reducing the waste loadings to many rivers. Many of these so-called "sewage farms" were abandoned due to urban growth and changing approaches to sewage treatment and disposal. In recent years, land application of sewage effluent and sludge has again received attention as a means of avoiding discharges to water courses and at the same time productively reusing the nutrients and water present in municipal wastes. As a result, the technology of land application has been developed to the extent that it is once again an accepted method of managing sewage wastes.

In Alberta, the Town of Granum first studied irrigation of forage crops with sewage effluent in 1969, followed by similar work at Taber. As a result of these early programs, there are now about 20 sewage effluent land application projects operating successfully in the Province and numerous others are being considered.

Applying sludge to farmland in Alberta was first studied at Calgary and Enchant in 1975, and now it is being successfully practiced by many municipalities in Alberta including Calgary and Edmonton.

It is hoped this booklet will encourage municipalities to consider land application alternatives during the planning stages of future municipal sewage treatment projects.

Land application of sewage effluent and sludge can take many different forms. The methods commonly used in Alberta and the potential benefits of application of sewage effluent and sludge to farmland are outlined in the following pages.



# SEWAGE – HOW YOU TREAT IT AND WHAT'S IN IT

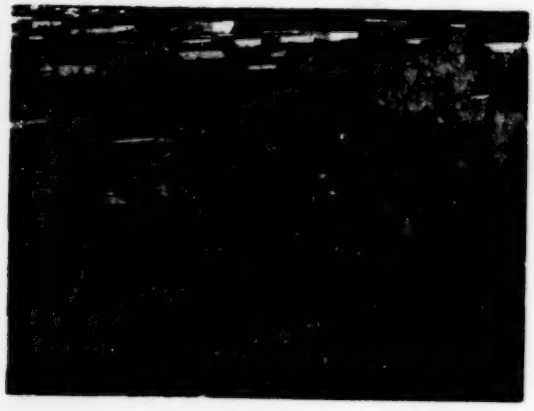
## BASIC SEWAGE TREATMENT PROCESSES

In most municipalities, sewage is collected in sewers and is conveyed to a central sewage treatment facility.

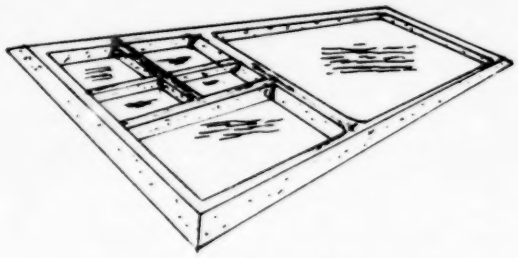
The types of sewage treatment systems employed in Alberta can be catagorized as follows:

- Waste stabilization ponds (lagoons)
- Aerated lagoons
- Primary Treatment Plants plus lagoons
- Secondary Treatment Plants

Treatment of sewage results in the production of two products for disposal, "clean" sewage effluent and sludge. Sewage effluent is normally disposed of either by discharging it to a receiving stream (or lake) or by applying it to land. Sludge is normally disposed of by sanitary landfilling, permanent storage in lagoons, incineration or application to farmland.



**MECHANICAL SEWAGE TREATMENT PLANT**



**SEWAGE LAGOONS**

## CHARACTERISTICS OF SEWAGE EFFLUENT

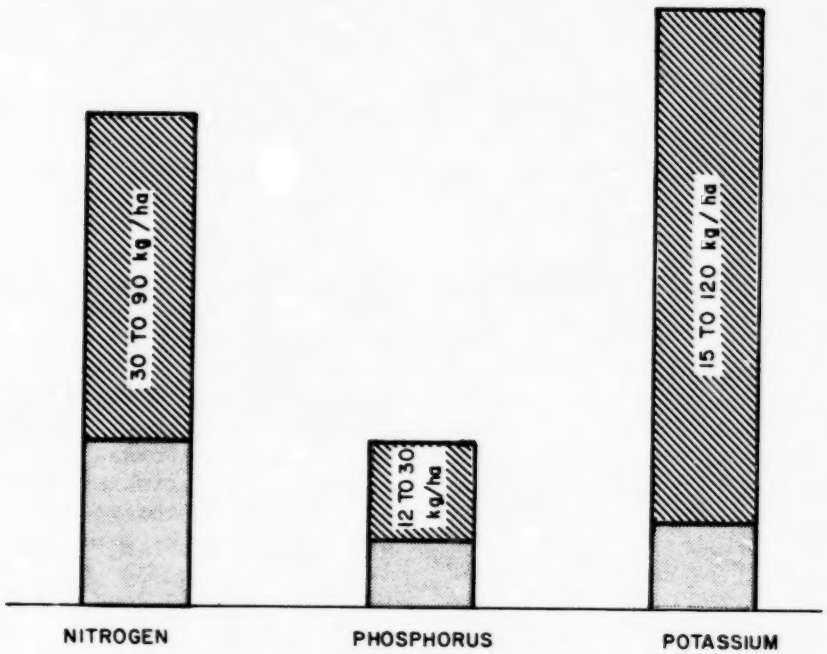
The characteristics of sewage effluent depend on the level of treatment provided. In Alberta, sewage must undergo at least primary treatment (settling) followed by storage before being applied to land. Typical characteristics of sewage effluent are summarized in the following table. Sewage effluent with these characteristics would be suitable for application to land provided the concentration of salts is not too high.

| TYPICAL CHARACTERISTICS OF SEWAGE EFFLUENT | | | | |
|---|---|---|---|---|
| Biodegradable Organic Matter ($BOD_5$) | 15 | to | 100 | mg/L |
| Suspended Solids | 15 | to | 100 | mg/L |
| Total Nitrogen | 10 | to | 30 | mg/L |
| Total Phosphorus | 4 | to | 10 | mg/L |
| Potassium | 5 | to | 40 | mg/L |
| pH | 6.5 | to | 9.5 | mg/L |
| 1 milligram per litre is approximately equal to 1 part per million on a weight basis | | | | |

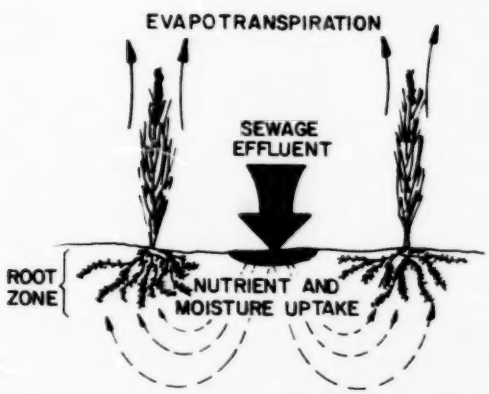
## RESOURCE VALUE OF EFFLUENT

Sewage effluents have considerable agricultural resource value and offer substantial benefits to the user. They normally contain an abundance of nutrients that are required for plant growth.

When 30 cm of a typical sewage effluent is applied to an area of land over the course of the growing season, the following approximate amounts of nitrogen, phosphorus and potassium can be added to the soil:




**AMOUNT OF NUTRIENTS ADDED TO SOIL WHEN 30cm OF SEWAGE EFFLUENT IS APPLIED PER YEAR**




Sewage effluent can also provide considerable benefit as a reliable source of irrigation water. In areas where crop production is limited by insufficient precipitation, effluent application can significantly improve crop production.

# LAND APPLICATION ALTERNATIVES FOR SEWAGE EFFLUENT – THE REUSE OPTIONS

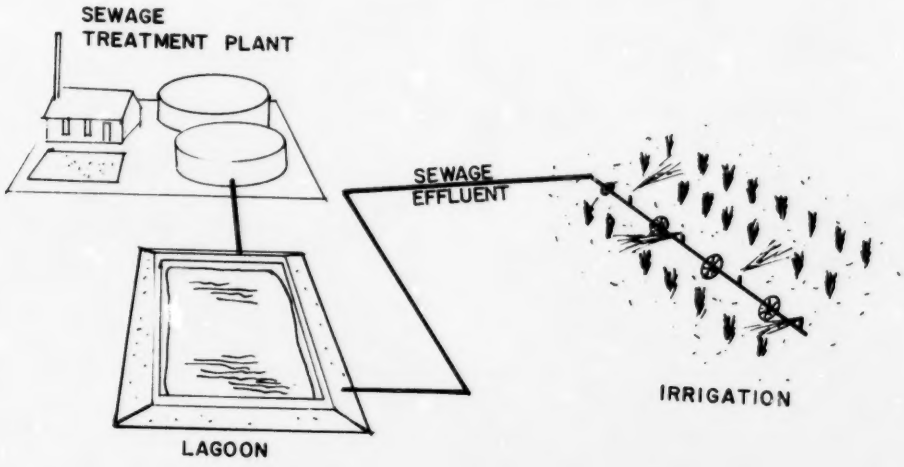
## STANDARD RATE IRRIGATION

Standard rate irrigation using sewage effluent involves application of the effluent to agricultural lands by spraying, sprinkling or surface spreading. The objective is to utilize the moisture and nutrients contained in the effluent to improve crop production while at the same time further treating and disposing of sewage effluent. Standard rate irrigation has its greatest potential in regions where there is not enough rainfall for optimum crop production.

In the standard rate irrigation system, effluent from the sewage treatment system is stored, most often in lagoons, until it is used for irrigation. Since irrigation cannot be carried out during the winter, the volume of the storage facilities must be relatively large if all the effluent generated during the non-irrigation season is to be stored.

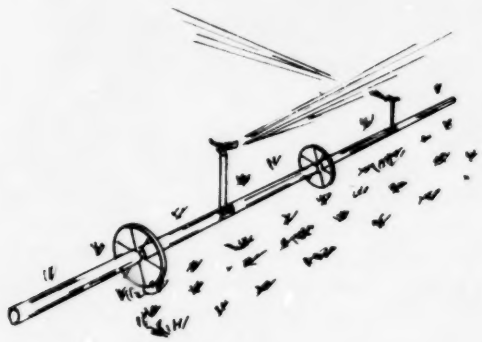
The sewage effluent is generally pumped or allowed to flow by gravity through a pipeline to the irrigation site. Transporting the effluent to the irrigation site may involve considerable capital cost for the pumps, pipeline and related equipment. Operating costs may also be high depending on the pumping requirements. Such factors as topography, distance from the sewage treatment facility to the irrigation site and the rate of pumping required must therefore be considered when planning a sewage effluent irrigation system.

Sewage effluent is applied to the cropland using conventional irrigation methods. In the spraying and sprinkler methods, the effluent is discharged into the air and falls to the ground much like rainfall. Spraying and sprinkling methods commonly used are the wheel roll system, the centre pivot



system, the handmove system, and the spray gun system.

In surface spreading methods, the sewage effluent is applied to the high part of a sloped field and flows by gravity over the field. The effluent that reaches the bottom end of the field is collected and either returned to the top of the field or discharged to a receiving stream (or lake).



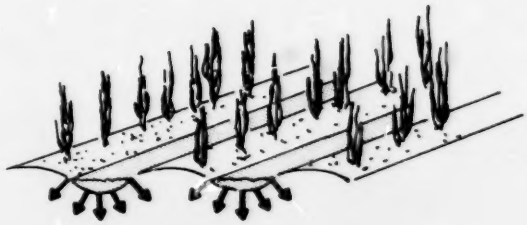
**SPRINKLER DISTRIBUTION (WHEEL ROLL)**

Since sewage effluents contain an abundance of nutrients, at least a part of the nutrient requirements of crops can normally be satisfied by irrigating with sewage effluents. This reduces or eliminates the need for commercial fertilizers. Crop production is thereby increased while reducing or eliminating the expense of fertilizers. In municipalities where effluent irrigation is being practiced, crop yields have been reported to be 20% higher than those from fields irrigated with local surface water. Similar increases may be achieved in other municipalities depending on local conditions such as effluent characteristics, soil type, crop types and climate.

Sewage effluents with high concentrations of dissolved salts, particularly sodium, are generally not suitable for irrigation since the salts will tend to accumulate in the soil and make it less productive. An accumulation of salts may occur even when effluents with low salt concentrations are applied. A late season irrigation is therefore generally used to leach accumulated salts from the root zone.

The possibility of implementing standard rate irrigation depends to a great extent on the types of soil at a site. Suitable sites will generally have a medium textured root zone with a well drained sub-soil. Preliminary information to help identify soil types and drainage characteristics of a potential site can be obtained from Land Classifications Standards for Irrigation published by Alberta Agriculture, Irrigation Division.

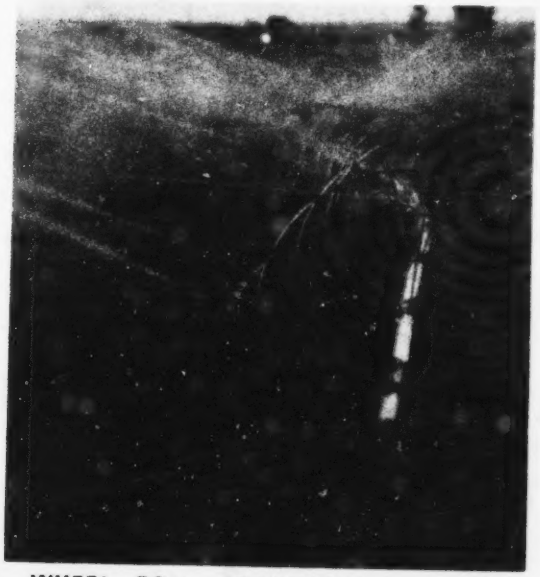
The topography of the site cannot be too severe or runoff of applied effluent into nearby water courses may occur. In hilly areas, runoff collection facilities may have to be installed. Slopes must also be compatible with the type of irrigation system used and the method of crop harvesting.



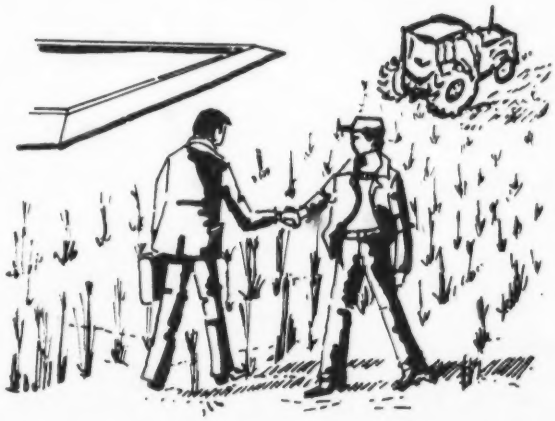
**SURFACE SPREADING**

Municipalities that plan to implement effluent irrigation are often able to assemble the land areas required through agreements with local farmers who wish to receive sewage effluent for irrigation. Cost may limit the viability of the irrigation option if land must be purchased or leased by the municipality.

A possible disadvantage of standard rate irrigation is the large areas of land that may be required. Land requirements will depend mainly on the volume of sewage to be applied. Larger volumes will require greater land areas. Land area is also affected by the moisture requirements of the crop being grown. Crops such as alfalfa and clover require more moisture than other crops such as oats and barley. A smaller land area is therefore required to apply a given volume of sewage effluent if alfalfa or clover is irrigated. The amount of effluent that can be applied to a given crop is also affected by the annual evaporation rate of the area.



**WHEEL ROLL IRRIGATION SYSTEM**



**CO-OPERATION BETWEEN MUNICIPALITY AND FARMER**

Many potentially disease-causing micro-organisms, such as bacteria, viruses and intestinal parasites are known to exist in sewage effluent. Despite the presence of these micro-organisms, the potential health hazard associated with irrigating crops with sewage effluent can be minimized by following certain precautions and guidelines which have been established by Alberta Environment.

The majority of the potentially harmful micro-organisms are killed over a period of time by exposure to strong sunlight, high temperatures and dry weather. The survival of these micro-organisms on plants is also affected by the stem and leaf structure of the plant.

Alberta Environment's guidelines limit the timing of effluent irrigation with respect to harvesting of crops and grazing of livestock. Effluent irrigation of certain crops that may be eaten raw or which have a leaf structure that could harbour micro-organisms, such as corn, is also not allowed.

Irrigation with sewage effluent can lead to contamination of groundwater. A careful review of local soil and subsoil conditions and comprehensive monitoring of the groundwater by the municipality or the farmer are therefore necessary to ensure that local groundwaters are protected.

The possibility of uptake of harmful amounts of toxic heavy metals by the plants is highly unlikely as most metals are removed from the sewage at the sewage treatment facility.

## HIGH RATE IRRIGATION

High rate irrigation is similar to standard rate irrigation except that the application rate is much in excess of the crop requirements. High rate irrigation is primarily a method of sewage effluent treatment and disposal with the added side benefit of increased crop production. Solids and some of the nutrients are removed from the sewage effluent as it percolates through the soil. Some of the nutrients are utilized by the crops. A portion of the sewage effluent percolates below the root zone and the potential for groundwater contamination is therefore much greater with this method of sewage irrigation.

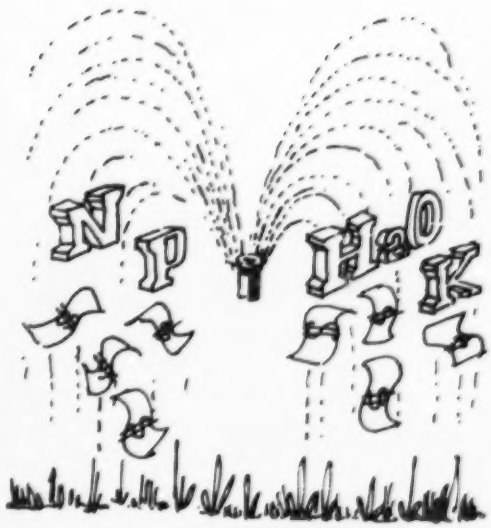
In Alberta, high rate irrigation is not commonly practiced. It may be suitable where raising the groundwater levels is desirable or in cases where standard rate irrigation is not feasible due to the large land area required. High rate irrigation may also be useful as an effluent disposal method in areas where no other method of sewage disposal is available.

CENTRE PIVOT IRRIGATION SYSTEM

## ECONOMIC IMPLICATIONS

Land application of sewage effluent provides several benefits to the users. These are summarized in the table below. Some of these benefits, such as increased crop production, are tangible items. Other benefits such as the elimination of effluent discharges to surface waters have a value which is difficult to estimate.

The cost items associated with land application systems are listed in the table below. These costs must be weighed against the benefits that may be achieved. In addition, the potential disadvantages associated with land application (listed below) have to be considered.



| BENEFITS |
| --- |
| increased crop production |
| reduction in fertilizer costs |
| reuse of nutrients and water |
| elimination of effluent discharge to surface waters |
| conservation of surface water sources |

| DISADVANTAGES |
| --- |
| the potential for disease transmission |
| potential for adverse effects on the soil and groundwater |

| COST ITEMS |
| --- |
| storage facilities |
| transmission facilities |
| pumping facilities |
| purchasing or leasing of land |
| irrigation equipment |
| runoff collection facilities |
| monitoring facilities |
| roads and fences |
| operation and maintenance |

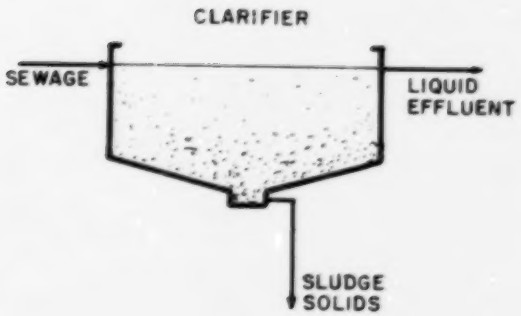
# SLUDGE – THE STUFF THAT SETTLES OUT

## CHARACTERISTICS OF SLUDGE

The composition of the sewage solids (sludge) produced during sewage treatment varies widely from community to community. The nature of this sludge is dependent on the type of sewage treatment process used and the nature of any industrial wastes discharged to the sewage treatment system.

Sewage sludges consist mostly of organic matter and water, but also contain varying quantities of metals, salts, sand and silt and plant nutrients. The organic matter contains many disease-causing micro-organisms as well as other harmless micro-organisms. Sludge treatment processes can be used to change the composition and characteristics of sludges.

Sludges that have undergone treatment are generally well bio-degraded and are suitable to apply to farmland. They generally have a solids content between 2% (watery) and 15% (like pancake batter) depending on the amount of water that is removed (called dewatering).




Sludges from the bottom of sewage lagoons are generally well degraded and fairly dense due to the natural compaction that occurs at the bottom of the lagoons.

The characteristics of a sludge will determine whether or not it is suitable for land application.

The typical composition of municipal sludges in Alberta is shown in the table below.

CHARACTERISTICS OF SLUDGES

Composition of Alberta Sludge as % of Dry Weight* (unless otherwise noted)

| | Minimum | Maximum |
|---|---|---|
| Solids | 1.0 | 20 |
| TKN*** | 1.0 | 11 |
| Ammonia Nitrogen | 0.02 | 4.1 |
| Phosphorus (total) | 0.25 | 2.3 |
| Calcium | 1.2 | 6.6 |
| Magnesium | 0.37 | 1.7 |
| Sodium | 0.002 | 3.4 |
| Potassium | 0.17 | 1.1 |
| Iron | 0.17 | 2.5 |
| Manganese** | 80 | 1000 |
| Zinc** | 390 | 1400 |
| Copper** | 280 | 1300 |
| Lead** | 50 | 1750 |
| Nickel** | 16 | 100 |
| Cadmium** | 4 | 20 |
| Chromium** | 22 | 1700 |
| Boron** | 7 | 33 |
| Mercury** | 1 | 6 |

* Sludge is dried to remove all water before analyses are done

** parts per million on a dry weight basis

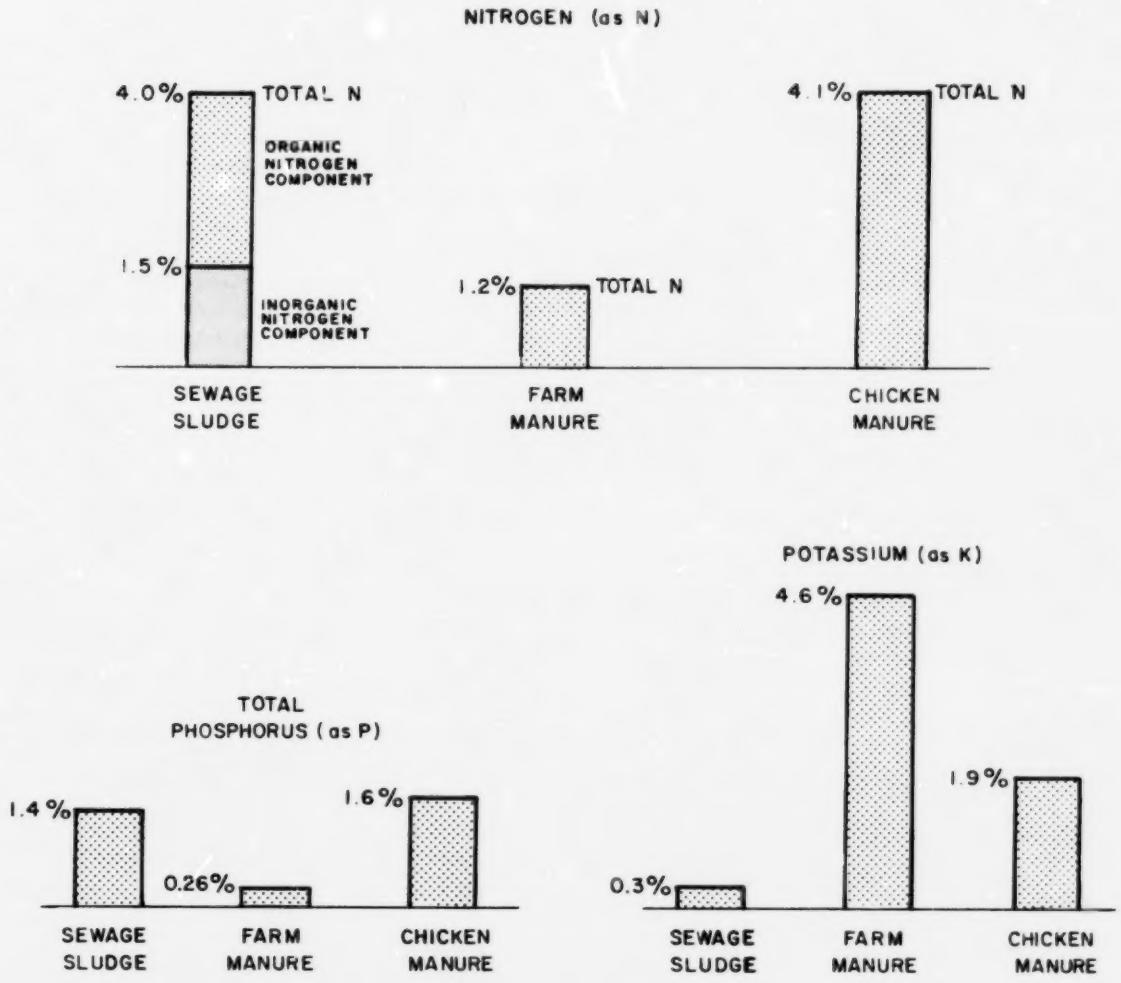
***Total Kjeldhal Nitrogen

Sludges may also contain disease causing viruses, bacteria and protozoan and helminthic (worm) parasites.

## RESOURCE VALUE OF SLUDGE

The agricultural resource value of municipal sludge is considerable, offering substantial benefits to the user. Sludge has a high nutrient content and is therefore an excellent fertilizer. The following figure illustrates the nutrient content of a digested sludge compared to average farm manure and chicken manure.

Sludge is also an excellent soil builder and conditioner as it contains a significant amount of organic matter.




**NUTRIENT CONTENT OF SLUDGES**

## BASIC SLUDGE TREATMENT PROCESSES

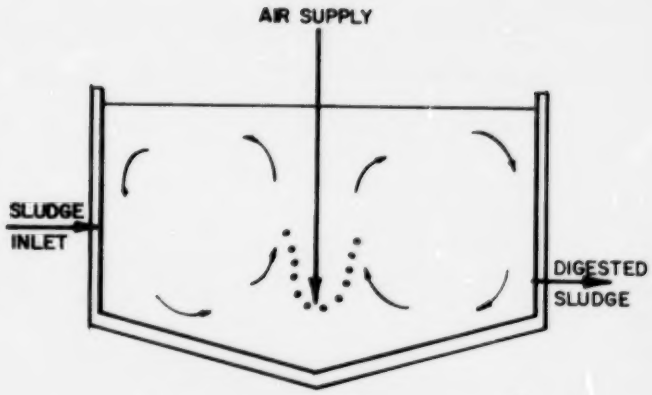
Sludge produced from the various sewage treatment processes can be considered as a liquid mixture of water and small organic particles resembling ground tea leaves.

Sludge treatment reduces the amount of sludge solids and makes the sludge more suitable for land application.

Thickening, dewatering or drying processes may be used to remove moisture from the sludge thereby reducing the volume that has to be handled or transported.

Sludge treatment is normally achieved by means of digestion. Two common methods of sludge treatment used in Alberta are aerobic digestion and anaerobic digestion.

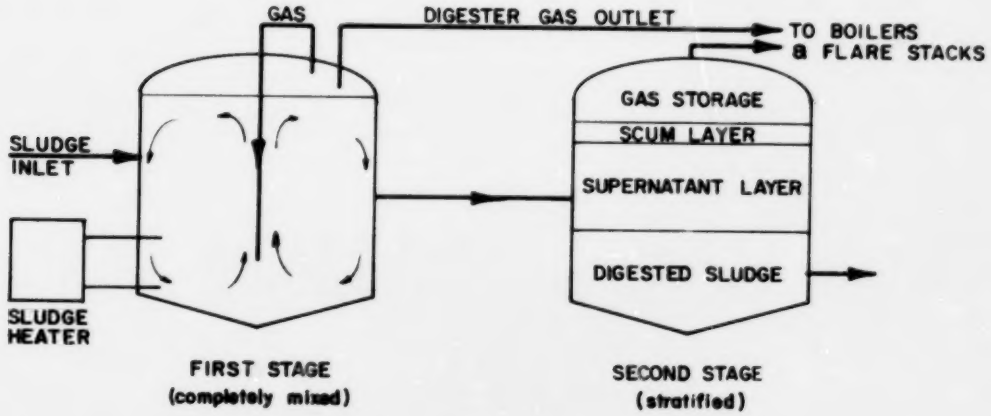
Anaerobic sludge digestion is a treatment process in which degradable substances in the sludge are broken down and stabilized by micro-organisms. Oxygen is excluded from the process. Most disease-causing organisms are destroyed by properly designed and operated anaerobic digesters.




**AEROBIC DIGESTION**

Aerobic sludge digestion is a treatment process similar in nature to the biological treatment processes used to treat sewage. Degradable substances in the sludge are stablized by micro-organisms, this time in the presence of oxygen. Most disease-causing organisms are destroyed by properly designed and operated aerobic digesters.

Sludge taken from the bottom of waste stabilization ponds (lagoons) or aerated lagoons does not normally have to be treated prior to application to land since considerable bio-degradation and reduction of disease-causing organisms take place during storage.




**TWO-STAGE ANAEROBIC DIGESTION**

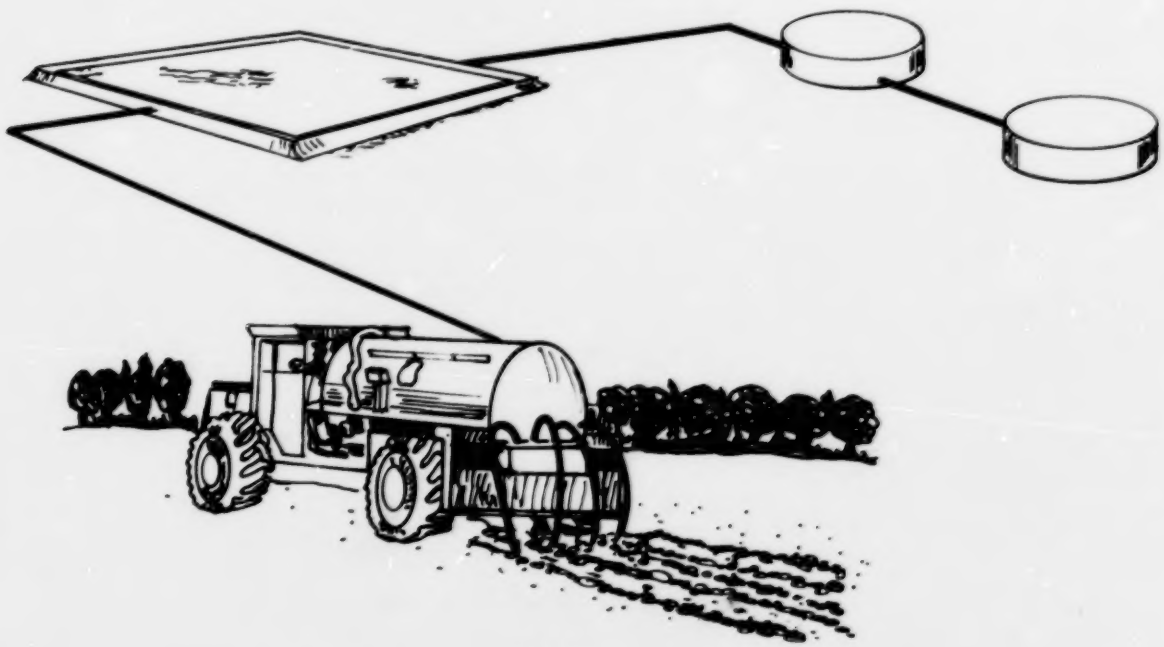
# SEWAGE SLUDGE APPLICATION TO FARMLAND – ADDING FERTILIZER AND SOIL CONDITIONER

Land application of sludge to farmland involves spreading of sludge onto the surface of fields or actually injecting it into the top layer of the soil. In this way, the nutrients, organic matter and moisture contained in sludge are used to enhance crop production and the disposal of sludge is achieved in an environmentally acceptable manner. Other sludge disposal methods such as incineration, land-filling and permanent storage do not utilize the resources contained in the sludge and may be less environmentally acceptable.

Sludge to be applied to land is usually loaded into tank trucks and hauled to the application site. In some cases, the tank trucks are equipped with spreading or injection equipment and can proceed directly onto the fields to apply the sludge. Often, however, the tank trucks are not able to enter the fields because of traction problems, particularly in wet weather. Where these factors are of concern, special field application equipment can be used. This requires the transfer of the sludge from the tank truck to the field equipment at the application site. The field equipment will generally be designed to impose low pressure on the soil to reduce soil compaction.

As soon as possible after surface spreading of sludge, the sludge should be tilled into the soil. Injection is carried out with special equipment that cuts a furrow, injects the sludge into the furrow and covers the furrow all in one operation.

Injection is the preferred method because potential problems such as runoff, odours and aesthetics are reduced or eliminated.



SURFACE SPREADING OF SLUDGE ON FARMLAND

Sludge contains most of the nutrients necessary for plant growth. A single application of sludge could add as much as 900 kg/ha (kilograms per hectare) of total nitrogen, 450 kg/ha of ammonium nitrogen and 500 kg/ha of phosphorus to the soil. Normally, commerical fertilizers will not be required for at least two years following the initial sludge application since many of the nutrients in the sludge are released gradually.

Sludge solids also consist of about 50% to 70% organic matter which greatly improves the water holding capacity of the soil.

All sludges must have a certain nutrient content in relation to their content of metals if they are to be considered for land application. This is to ensure that only sludges with high nutrient-to-metal ratios are applied to land so the objective of nutrient recycling is achieved and land application does not become a means of dumping sludges with high concentrations of metals.

The suitability of a site for sludge application will depend on the local soil characteristics, topography and groundwater depths. Suitable soils will have a minimum pH of 6.5 and be medium to fine textured. Flat and level sites are more suitable since the potential for runoff is less and the spreading or injection equipment will be able to operate more easily. The greater the depth to the groundwater table the better since the potential for groundwater contamination is reduced.

The land area required for sludge application will vary from location to location. Alberta Environment has established guidelines to limit the application rates according to the type of sludge, site characteristics, and the solids, nutrient and metal content of the sludge.

Sludge may contain disease causing bacteria, viruses and parasites. There are more of these micro-organisms in sludge than there are in sewage effluents because many of the organisms contained in the raw sewage settle out and concentrate in the sludge. The number and types of these micro-organisms present in sludge will vary depending on the characteristics of the raw sewage and the types of sewage treatment and sludge treatment used.

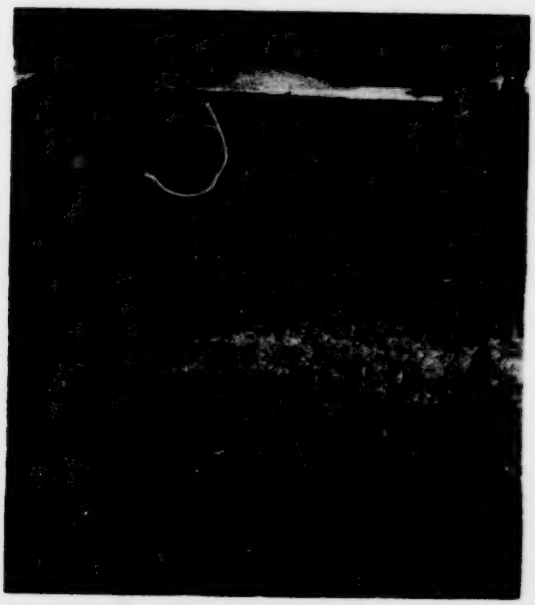
Both digested and undigested sludges are suitable for land application. Sludge treatment by anaerobic or aerobic digestion will greatly reduce the numbers of harmful micro-organisms contained in sludge and therefore digested sludges are preferred for land application. Sludge taken from the bottom of waste stabilization ponds or aerated lagoons normally has fewer harmful micro-organisms than raw sludge. Therefore, these sludges are more suitable than raw sludges for land application.

**INJECTING SLUDGE INTO FARMLAND**

Application of sludge to farmland may present a possible health risk if disease causing micro-organisms in the sludge survive in the soil and contaminate crops. The survival of such micro-organisms in soil and on plants is affected by factors such as:

- climate
- soil type
- moisture
- soil temperature
- soil pH
- soil organic matter concentration
- type of crop

The health risks can be reduced to a very low level by restricting application to lands intended for production of forage crops, oil seeds, small grains, trees and commercial sod. Lands that may be grazed by dairy cattle or used to grow root crops or crops to be eaten raw should not be considered for sludge application. Direct grazing of crops should not be allowed for a period of three years following sludge application.



Sludge contains potentially toxic metals such as cadmium, copper, molybdenum, nickel and zinc. These substances may accumulate in the soil to levels that are toxic to crops or may be taken up by the plants and pose a potential health hazard to humans and grazing animals. Sludge application guidelines generally take into account the concentration of metals in sludge and restrict their addition to the soil.

With application of sludge there is a potential for surface water contamination as a result of runoff. Application is therefore generally not permitted on ice or snow-covered fields or frozen soils when injection or tillage is not possible.

Care must also be taken to ensure land application of sludge does not contaminate groundwater, particularly in areas where the groundwater table is high.

## LAND RECLAMATION

Sludge can be applied to marginal land to improve the productivity of the soil. Sludge has also been used to reclaim disturbed land such as abandoned mine quarries, but it must be well treated to ensure that no nuisance conditions will result from its use.

An example of a mine tailings area at Blairmore that has been reclaimed through sludge application is shown in the photo opposite.

## ECONOMIC IMPLICATIONS

Land application of sludge to farmland provides substantial benefits to both municipalities and farmers. These are summarized in the table opposite. Some of these benefits, such as increased crop production are tangible items. Other factors, such as environmental acceptability are difficult to evaluate.

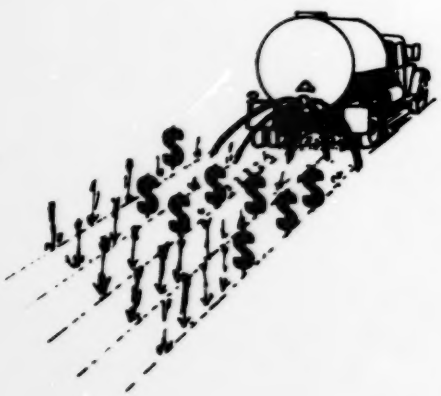
A sludge application operation will involve costs for certain facilities and equipment which are listed in the table below.

These cost items must be compared to the potential benefits and considered against alternate methods of sludge disposal. In addition, the disadvantages associated with land application, which are listed opposite, must be considered.

| BENEFITS |
| --- |
| increased crop production |
| reduction in fertilizer costs |
| recycling of nutrients |
| soil conditioning |
| a simple and low cost method of disposal |
| generally environmentally acceptable |

| DISADVANTAGES |
| --- |
| potential health hazards |
| potential adverse effects on the soil and groundwater |
| the potential for odours and aesthetic problems |

| COST ITEMS |
| --- |
| storage facilities |
| equipment to haul from source to fields |
| application equipment |
| operation and maintenance |

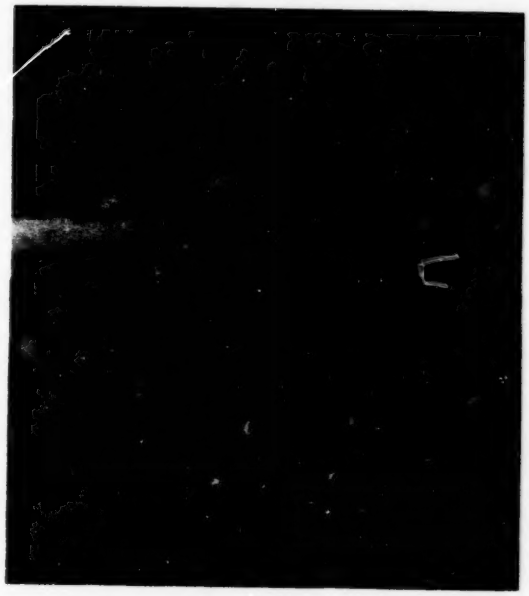


Land application of sludge to farmland is one of the least costly methods of sludge disposal and is the only method that re-utilizes the nutrients, moisture and solids contained in sludge. Other methods such as incineration involve a high capital cost and may be energy intensive.

# PLACES WHERE REUSE IS PRACTICED

In Alberta, sewage effluent irrigation is presently being practiced by the Towns of Taber and Claresholm. Irrigation of farmland with sewage effluent has also been successfully implemented in other provinces in Western Canada.

The Town of Taber applies effluent to approximately a half section of land using the wheel roll irrigation system. The entire effluent irrigation system is owned, managed and operated by the Town. Revenue is earned through the sale of the crop grown which is normally alfalfa.



**TABER ALBERTA**

**CLARESHOLM, ALBERTA**

The Town of Claresholm applies effluent from its sewage lagoon system to approximately a half section of land. The effluent delivery system is owned by the Town and the land is owned by a farmer who uses his own centre-pivot system to apply the effluent. The crop grown is normally alfalfa.

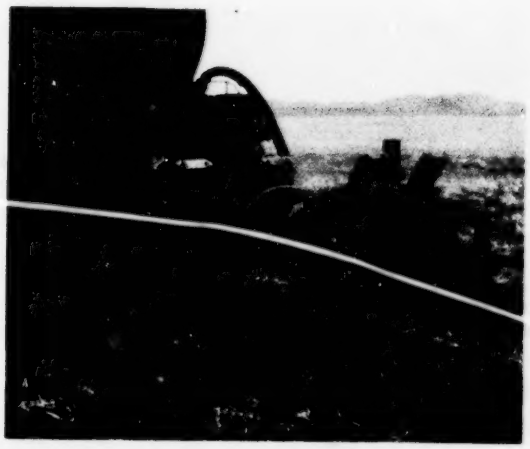
In Saskatchewan, effluent irrigation was first carried out at Swift Current beginning with a pilot study in 1973. In 1974, a full scale effluent irrigation system was introduced and the City now applies all of its effluent to approximately one and one-quarter sections of cropland owned by four farmers.

SWIFT CURRENT, SASKATCHEWAN

Several municipalites in Alberta have successfully practiced land application of sludge to farmland. Four of these operations are described here to provide an example of the processes and procedures involved.

The cities of Calgary and Edmonton practice application of sludge to farmland on an on-going basis. Both cities have activated sludge treatment plants and treat their sludge by anaerobic digestion prior to land application.

Calgary applies 185,000 cubic metres of sludge per year by injection. The sludge is applied to nearby farmland using three city-owned sludge injectors.



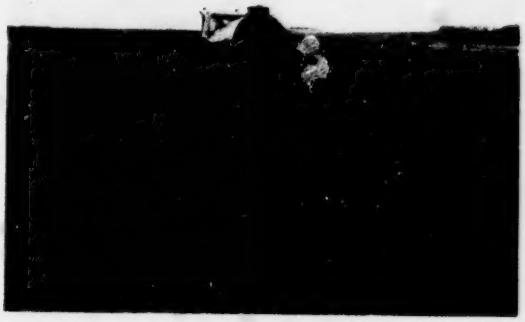
CALGARY, ALBERTA

The City of Edmonton applies 150,000 cubic metres of sludge per year to farmland. The sludge is stored in lagoons and then pumped into tank trucks and delivered to nearby farmland where it is applied by surface spreading.

EDMONTON, ALBERTA

In the summer and fall of 1982, the Town of Bentley applied 2,300 cubic metres of sludge from its sewage lagoons to farmland. The sludge was applied by surface application at a cost of $1.25 per cubic metre. The 1983 barley crop harvested from this farmland was reported to be excellent.

PUMPING SLUDGE FROM THE SEWAGE LAGOONS AT BENTLEY, ALBERTA

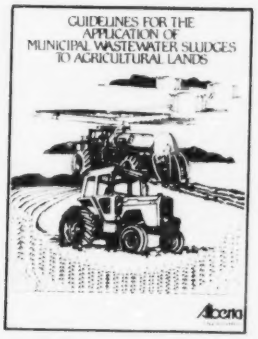


RED DEER ALBERTA

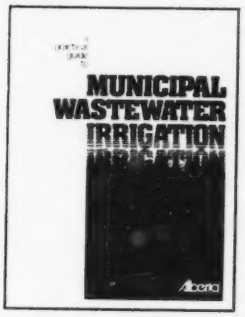
In 1981 the City of Red Deer carried out a pilot sludge injection program in which 9,300 cubic metres of anaerobically digested sludge was removed from the City's sludge storage lagoons and injected to nearby farmland at a cost of $15 per cubic metre.

# WHERE TO GET MORE INFORMATION

Alberta Environment has prepared two documents which can be used as guidelines for those who are considering land application of sewage effluent or sludge.




*Alberta Environment's Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands outlines all the factors to be considered when planning sludge application to farmland, including allowable application rates, approval requirements and procedures and the general benefits and potential drawbacks associated with this method of disposal.*




*Alberta Environment's A Practical Guide to Municipal Wastewater Irrigation contains practical information to help determine whether irrigation will be feasible in a given area, what government approvals are necessary and where more detailed technical information can be obtained.*

More specific information on sewage effluent irrigation is contained in the *Canadian Land Treatment Design Manual* published jointly by Alberta Environment and Environment Canada.

All of these documents as well as more information on Land Application of Sewage Effluent and Sludge are available from:

Alberta Environment
Standards and Approvals Division
Municipal Engineering Branch
4th Floor, 9820 - 106 Street
Edmonton, Alberta
T5K 2J6

Telephone: (403)427-5877